CROP BREEDING AND APPLIED BIOTECHNOLOGY

CULTIVAR RELEASE

NIA-Shaheen (CIM-04-10): A high-yielding, drought-tolerant wheat variety

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Abstract: *The wheat variety NIA-Shaheen (CIM-04-10) has high grain yield and modern plant architecture. It has wide adaptability, increased tiller production, bold grains, high starch and protein content, and good tolerance to disease and environmental stresses, particularly water stress. NIA-Shaheen has high yield potential (7184 kg ha^{-1}).*

Keywords*: Bread wheat, disease resistance, environmental stresses, grain yield.*

INTRODUCTION

Wheat (*Triticumaestivum* L.) is the second most important cereal crop in the world,with production of 762 million tons per year (FAO 2020). It accounts for 30% of grain production and 45% of cereal-based nutrition, thus establishing it as a major food crop globally. According to a United Nations report, world population is projected to increase to almost 10 billion by 2050 (UN 2015). In the face of the rising global population, wheat production and yield improvement have become crucial. Food production in developing countries must increase 70-110% by 2050. The problem of food security is exacerbated by prevailing climatic changes. These changes contribute to higher mean temperatures, increasing water short ages (Sehgal et al. 2018); there may be a 55% increase in water requirements by 2050, from 3500 to 5425 km^3 worldwide (Islam and Karim 2018). In wheat, water stress, especially during the reproductive stage, decreases the quantity of grain (Dong et al. 2017). Water stress alone can reduce wheat grain yield, with estimated average yield decreasing from 17% to 70% (Nouri-Ganbalani et al. 2009).

Generally, multiple stresses occur in the field in a collective manner. It has thus become indispensable to develop crop cultivars well equipped with tolerance to multiple stress factors to mitigate the constraints of climatic changes and to meet the nutritional demands of the human population (He et al. 2018). In addition, diseases such as leaf rust (*Puccinia recondite)* and stripe/yellow rust (*Puccinia striiformis)* are among the factors destructive to wheat. Such pathogens can attack diverse grass species and result in yield losses of up to 60% in leaf or stripe rust, and 100% in stem rust (Arain et al. 2017). Changing climates create new races of pathogens, and resistant varieties become susceptible. Hence, the release of new, more promising, stress-tolerant varieties is key for improvement of genetic gains (Benin et al. 2020). NIA-Shaheen meets the requirements for release of a new variety, with high yield, stability, better quality, resistance to diseases, and tolerance to stresses (Federizzi et al. 2012).

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To that end, the NIA-Shaheen wheat variety developed by NIA, Tando Jam, has been presented for cultivation in normal and late sowing systems of the Sindh province in Pakistan. The cultivar was initially selected from exotic germplasm received from CIMMYT in the year 2003-04 and evaluated in different trials with competing genotypes. It has tolerance to diseases, resistance to lodging, bold grain, high grain yield, and superior quality. Weather events such as wind and rain storms can result in lodging that can cause up to 80% yield loss (Feng et al. 2019). In national trials, the variety was ranked in first place in Sindh province and third across Pakistan. The variety has good performance under water deficit conditions. The name NIA-Shaheen was based on the name of the development institute (NIA) and the term "Shaheen" (meaning majestic).

The Tando Jam wheat breeding program of the Nuclear Institute of Agriculture (NIA) has been actively working to develop new improved varieties using conventional (hybridization and mutation) breeding methods. So far, NIA has developed 15 wheat cultivars with diverse valuable traits, including tolerance to abiotic and biotic stresses such as drought, salinity, and rust diseases. 'NIA-Shaheen' is an excellent choice for wheat growers/farmers of the Sindh province, due to its wide adaptability to this environment. It is well equipped with adesirable combination of traits to assume the local challenges of increasing population and food demands by producing high yields and showing resistance against biotic and abiotic stresses, especially water stress.

BREEDING METHODS AND DEVELOPMENTAL HISTORY

NIA-Shaheen, previously coded as CIM-04-10, with pedigree/parentage PBW 343*2/KONK, is a conventionally bred wheat variety introduced by the Nuclear Institute of Agriculture (NIA), Tando Jam. It was selected from exotic germplasm (F_2) received from CIMMYT, Mexico, in the 2003-04 crop year (Figure 1). The line was tested in preliminary yield trials along with 13 other advanced lines and two checks, 'Sarsabz' and 'Kiran-95', in 2007-08 (Table 1). 'NIA-Shaheen' was tested in an advanced strain yield trial (AST) along with the 14 competing entries and two checks, *viz*., 'Sarsabz' and 'Kiran-95', in 2009-10 (Table 2). 'NIA-Shaheen'and fourteen advanced lines were further tested in multi-location adaptive yield trials, along with three check varieties,viz., Sarsabz, TD-I, and TJ-83, conducted in five major wheat-producing districts of Sindh province for two consecutive crop years (2011-2013), as shown in Table 3. Additionally, NIA-Shaheen was tested for different agronomic traits and for standardization of production technology in different agronomic evaluation-based trials. In the agronomic trials, the line was tested on different sowing dates and at different row spacings,

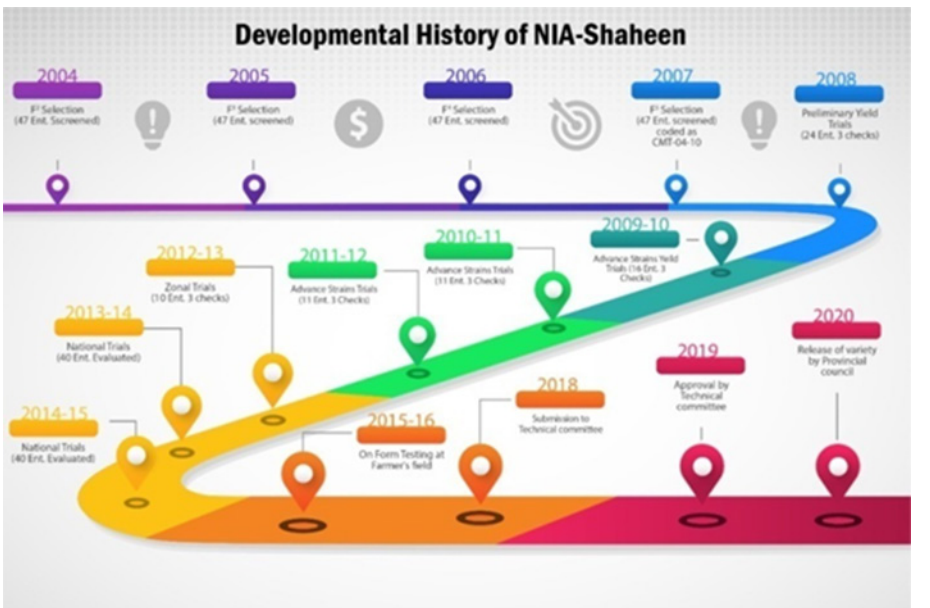

Figure 1. Schematic presentation of the developmental history of 'NIA-Shaheen'.

seeding rates,and irrigation levels to optimize the irrigation providedand to study the effects of drought on final yield potential. Each agronomic trial was sown in a 9-m^2 plotconsisting of six 5-m length rows using a RCB design with three replicates. Based onitshigh grain yield potential, the CIM-04-10 line was promotedto the national uniform wheat yield trials (NUWYT), where it was tested along with 39 candidate wheat lines for two consecutive years (2013-14 to 2014-15). Parallel to testing for the yield potential and suitability of the line under different climatic conditions, 'NIA-Shaheen' was also screened for different wheat diseases, specifically for rust resistance in hotspot areas of Pakistan under the national wheat disease screening nursery (NWDSN) by the Crop Disease Research Institute (CDRI) in Islamabad, Pakistan. Extensive yield trials were conductedin farmers' fields in 2015-16. The proposal of the candidate line CIM-04-10 was presented

Table 1. Performance of 'NIA-Shaheen' in preliminary yield trials

S/No.	Genotype	DH	PH	SL	SPS	GPS	MSY	GS	GY
1	CIM-04-9	74.3f	106.0de	12.4b	21.4ab	68.5a	3.17ab	3.20b-e	4167ab
2	CIM-04-10[1]	75.3ef	108.8cd	12.6ab	21.7a	67.9a	3.38a	3.69a	4515a
3	CIM-04-11	75.3ef	107.5cd	11.4c	20.7a-d	60.7c-f	2.83b-e	2.93fg	3715bc
4	CIM-04-14	78.3bcd	99.9g	11.4c	19.6f	59.3ef	2.67de	3.02efg	4515a
5	CIM-04-16	75.7ef	109.0cd	12.4b	21.1abc	67.7abc	3.07abc	3.21b-e	3681bc
6	CIM-04-17	75.3ef	104.4e	12.3b	20.7bcd	67.0ab	3.08abc	3.24b-e	4015ab
7	CIM-04-18	77.0de	107.9cd	11.7c	19.7ef	66.5abc	3.05bc	3.39b	2640def
8	CIM-04-19	80.0ab	117.2a	12.9ab	21.1abc	66.6a	2.96bcd	3.30bc	2917def
9	CIM-04-20	79.7abc	112.9b	12.6ab	18.4g	64.5a-e	2.89b-e	3.18b-e	3298cd
10	CIM-03-4	79.3bc	100.0g	11.5c	20.3c-f	65.6a-d	3.01bcd	3.03d-g	3194cde
11	CIM-03-6	78.0cd	102.9efg	11.2c	21.4ab	67.2ab	2.92b-e	3.14c-f	2985de
12	CIM-03-9	81.3a	1.29efg	11.6c	20.6b-e	61.9c-f	3.03bc	3.01efg	3785bc
13	CIM-03-17	78.3bcd	110.3bc	12.4b	20.6b-e	58.4f	2.60e	2.83g	4027ab
14	CIM-03-19	79.0bc	112.5b	12.5b	21.1abc	59.9def	2.78cde	2.84g	3125cde
15	Sarsabz	70.7g	103.9ef	12.3b	20.0def	65.1a-d	2.79cde	3.26bcd	2569ef
16	Kiran-95	75.0f	101.2fg	13.1a	20.3c-f	65.1a-d	3.14ab	3.21b-e	2256f

Note: Means followed by different letters within a column for each trait have significant differences at the level of the LSD test (P< .05). S/No: Serial number; DH: days to heading; PH: plant height (cm); SL: spike length (cm); SPS: spikelets per spike; GPS: grains per spike; MSY: main spike yield (g); GS: grain per spikelets; GY: grain yield (kg ha^{-1}). Genotypes 15 ('Sarsabz') and 16 ('Kiran-95') are commercial checks. [1] NIA-Shaheen was previously coded as CIM-04-10.

Table 2. Comparative performance of wheat genotypes in Advanced Strain Yield Trials

S/No.	Genotype	DH	PH	SL	SPS	GPS	MSY	TSW	GY
1	CIM-04-9	75.0g	98f	11.4e-h	18.7b	56.4abc	2.25cd	39.31ef	5239fgh
2	CIM-04-10[1]	75.0fg	101cde	12.2a	18.7b	61.5a	2.84a	48.06a	6429a
3	CIM-04-11	76.3ef	99 ef	11.9a-d	19.7a	54.3bc	2.73ab	46.69a	5731cde
4	CIM-04-14	75.0fg	92g	11.3fgh	18.5bc	51.5c	2.40a-d	44.73abc	6209ab
5	CIM-04-16	74.3g	99ef	12.1ab	18.7b	53.0bc	2.21cd	40.30def	5764cd
6	CIM-04-17	75.7efg	103bc	11.2gh	18.1bcd	57.7abc	2.44a-d	39.66ef	5951bc
7	CIM-04-18	75.7efg	101cd	10.6i	17.5de	52.2bc	2.17cd	39.39ef	5491d-g
8	CIM-04-19	80.3a	103b	11.5efg	18.3bc	52.7bc	2.31bcd	40.36def	5217fgh
9	CIM-04-20	80.0ab	103b	11.7b-e	17.0 e	57.2abc	2.6abc	41.45cde	5271fgh
10	CIM-03-4	78.0cd	100def	10.5i	18.0 bcd	56.9abc	2.74ab	46.00ab	5418e-h
11	CIM-03-6	77.0de	101cd	10.6i	18.2bcd	58.6ab	2.03d	36.21f	5541def
12	CIM-03-9	80.3a	101cd	11.1h	17.8cd	57.2abc	2.24cd	38.39 ef	5292fgh
13	CIM-03-17	80.0ab	104b	12.0abc	18.8b	54.7bc	2.13cd	38.97 ef	5115h
14	CIM-03-19	78.7bc	108a	11.7c-f	18.2bcd	56.6abc	2.53abc	44.29a-d	5184gh
15	Sarsabz	63.3i	108a	11.6def	17.5de	51.3c	2.32bcd	43.97a-d	5383fgh
16	Kiran-95	72.3h	103b	11.3fgh	18.0 bcd	57.5abc	2.51abc	42.22b-e	5485d-g

Note: Means followed by different letters within a column for each trait have significant differences at the level of the LSD test, P< .05. S/No: Serial number; DH: days to heading; PH: plant height (cm); SL: spike length (cm); SPS: spikelets per spike; GPS: grains per spike; MSY: main spike yield (g); TSW: 1000 seed weight; GY: grain yield (kg ha^{-1}). Genotypes 15 ('Sarsabz') and 16 ('Kiran-95') are commercial checks. [1] NIA-Shaheen was previously coded as CIM-04-10.

Table 3. Grain yield performance of 'NIA-Shaheen' with percentual increase (% Inc.) over check cultivars in multi-environment yield trials at five locations in Sindh, Pakistan

Locations	*NIA-Shaheen*	*Check cultivars*						*Site mean*
		T.D-1	*% Inc.*	*Sarsabz*	*% Inc.*	*TJ-83*	*% Inc.*	
Radhan	4577	1750	62	2111	54	2611	43	2692
Umerkot	4056	3278	19	3667	10	3222	21	3502
Thatta	6689	6244	07	6189	07	5667	15	6129
Kunri	6111	5778	05	4389	28	5667	04	5664
T. Jam	4575	3444	25	4222	08	3778	17	3663
Gen. mean	4576	4360		4351		4395		4305

Note: Gen. mean: genotypic mean; % Inc: Percent (%) increase over local checks. T.D-1, Sarsabz and TJ-83 are used as check cultivars.

in the Technical Sub-Committee for Approval of Cultivarsand Techniques, Government of Sindh, Pakistan. Finally, based on the distinctness, uniformity, and stability (DUS) features of CIM-04-03, the proposal was unanimously approved in the 62nd meeting of the provincial Seed Council, Government of Sindh, in Karachi on 29 January 2020, and the cultivar was released for general cultivation in Sindh province as a high yielding, lodging-resistant, and disease-tolerant cultivar.

AGRONOMIC FEATURES AND PERFORMANCE

The agronomic traits of the NIA-Shaheen cultivar (previously CIM-04-10) are provided in Tables 1 and 2. 'NIA-Shaheen' has modern plant architecture with average plant height, 103 cm; days to heading, 78.2; medium maturity life cycle, 125-130 days; broad erect leaves; semi-erect flag leaf with a slight twist and waxy sheath; a stiff, erect stem; and high tillering capacity, 493/tillers m^2. 'NIA-Shaheen' has a long spike, 12.4 cm; spikelets per spike, 21.0; grains per spike, 61.3; and main spike yield, 3.0 g. The cultivar has bold grains of amber color; high thousand seed weight, 45.0g; seed length, 6 mm; seed width, 3.5 mm; and seed thickness, 3 mm. It has good bread-making quality; high tertest weight, 78.7 kg hl^{-1}; good protein content, 13.8%; starch content, 55.7%; and wet gluten content, 27%, as shown in Table 6. The cultivar is also resistant to lodging; lodging is a major obstacle in achieving yield potential, due to high wind speed, and is considered essential in this system.

Table 4. The best grain yield (kg ha^{-1}) performance of 'NIA-Shaheen' in NUWYT trials across Pakistan (2013-14; 2014-15)

S/No.	Location	GY (NIA-Sh)	GY L.C	% Inc.	S/No.	Location	GY (NIA-Sh)	GY L.C	% Inc.
				2013-14					
1	MARC. J	2369	1658	43	10	ARF-Kar	5142	4016	28
2	CCRI-PS	2874	2243	28	11	Sargodha	3671	2638	39
3	Mardan	5361	4417	21	12	Multan	4028	3341	21
4	Charsada	5028	4444	13	13	Khanewal	4276	3570	20
5	NIFA-Pr	3840	2866	34	14	WRI-FSD	4638	4306	08
6	AJK	1829	1506	21	15	J. Arain	4216	3760	12
7	Sahiwal	3862	2959	31	16	Gurh More	5918	5322	11
8	PRI-KSK	3345	2764	21	17	T. Jam	4417	3834	15
9	Gujranwala	2362	1664	42	18	Sakrand	3095	2745	13
2014-15									
1	Kal.Kot	4201	3687	14	10	RARI-BP	3714	2546	46
2	RRS-BP	3944	3670	22	11	WRI-Tjam	4537	2488	82
3	Sahiwal	4564	3856	18	12	Mardan	7184	5333	35
4	Kala.SK	3173	2471	28	13	MARC-J	1937	1583	22
5	Fort.A M	4500	4000	13	14	BARS-Kt	2862	1597	79
6	Kikri.RYK	5753	4727	22	15	AJK	2353	1935	22
7	J. Arain	4567	3728	23	16	AZRC-Q	2084	1660	25
8	Jhanian	3535	2446	45	17	M-Sawat	2402	1658	45
9	Ali.P.M.G	5611	4278	31	18	AZRI- BP	2733	2068	32

Note: S/No: Serial number; NIA-Sh: Nia-Shaheen; GY: grain yield (kg ha^{-1}); L.C: Local check; % Inc: Percent increase. Data source: NUWYT 2013-14 and 2014-15.

Table 5. Performance of 'NIA-Shaheen' for rust resistance in NUWYT based on RRI value

S. No.	Entry	2013-14	2014-15		
		Leaf rust	Leaf rust	Yellow rust	Stem Rust
1	V-10110	6.53	5.85	2.78	3.84
2	TW96018	8.13	7.83	2.09	6.13
3	NIA-Shaheen	8.94	8.86	4.16	6.4

Note: S/No: Serial number; Rust data is provided as RRI (Relative rate index) values of the candidate lines. Data source: NUWYT 2013-15.

Table 6. Seed quality traits of 'NIA-Shaheen' compared with the check cultivars (2013-14)

Line	1000 Seed weight (g)	Test weight (kg hl^{-1})	Starch (%)	Grain protein (% d.b)
		2013-14		
NIA-Shaheen	43.4	75.1	53.3	13.8
TD-1	26.0	75.2	52.9	13.8
GALAXY 13	36.1	71.9	55.6	11.8

Note: kg hl^{-1}: *kilograms per hectoliter;* % d.b: *Grain protein concentration.* Data source - NUWYT results.

'NIA-Shaheen' has been evaluated in the Preliminary Yield Trial (PYT), AST, and major yield trials for its distinctness from other local cultivars based on its morphological traits (Tables 1 and 2). 'NIA-Shaheen' has also been evaluated in multi-location zonal (Table 3) and national NUWYT (Table 4) trials, which provide reliable data on its performance, adaptability, and stability (Woyann et al. 2019). A 10 to 15-year inbreeding process is usually required to develop a new crop cultivar. The fundamental prerequisite for a candidate cultivar is that it be distinct, uniform, and stable in its characteristics and performance (Saccomanno et al. 2020). Before this cultivar was released, the Federal Seed Certification and Registration Department (FSC&RD) provided the certificates/registry for distinctness, uniformity, and stability (DUS) of the candidate line. The DUS provides the descriptive evaluation to identify the cultivar from other existing cultivars, using the morphological traits, and also checks its uniformity and stability (Saccomanno et al. 2020). The results provided by the FSC&RD suggested that the cultivar NIA-Shaheen is uniform, distinct, and stable than all other existing cultivars of Pakistan.

NIA-Shaheen showed tolerance to rust diseases viz., leaf (RRI: 8.94) and black stem rust (RRI: 6.4) and moderately tolerant (RRI: 4.16) to yellow rust (Table 5). NIA-Shaheen presented in national varietal trials (conducted all over the country) with the highest yield of 7184 kg ha^{-1}, which was at par to local check (Table 4). The mean grain yield of cultivar was 4015 kg ha^{-1} in pooled data on 30 locations conducted all over the country and remained at par with local control and other check cultivars in yield, it includes excellent features for quality and disease performance (Table 4). Moreover, its DUS characteristics are suitable for its release and meet the criterion "new to market" required by the production chain (Schiocchet et al. 2014).

SEED PRODUCTION AND DISSEMINATION

The cultivar was released (No. f.1-15/DUS report/ 272-73) on the market for general cultivation in the Sindh province, with initial seed availability of 3750 kg bags for the 2021 crop year. In coming years, greater seed quantity will be available to public and private sectors for further proliferation and dissemination of this cultivar among farmers.

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